# EM375 MECHANICAL ENGINEERING EXPERIMENTATION

## THERMOCOUPLE LABORATORY

**PURPOSE:** The objective of this laboratory is to give the student some experience working with first order systems. Thermocouples will be used as a model for first order system behavior. Students will gain experience by making thermocouples, and will explore their transient response characteristics. Particular attention will be focused on the concept of the time constant.

**THEORY:** The most elementary thermocouple consists of two dissimilar metals joined at two locations, as illustrated below.


When the temperatures of the two junctions, $T_1$ and $T_2$, are different, a net EMF is generated. The magnitude of the EMF is approximately proportional to the temperature difference. So, if the temperature of one of the junctions is maintained at a known value (or reference temperature) then the temperature of the other junction can be determined from the magnitude of the generated EMF. A more detailed discussion of thermocouples can be found in chapter 9 of the text.

**PROCEDURE:** There are two parts to this lab. One part is to make thermocouples using three different techniques, and verify the performance of the thermocouples. The other part is to determine the transient response characteristics of one of your thermocouples.

### Part 1: Making Thermocouples.

Each individual person will make three thermocouples, one for each of three different manufacturing techniques. The techniques are twisted wire, cool arc and heliarc. You will be introduced to these methods during the lab class. The steps for each thermocouple are:

1. Strip approx. 0.5 inch of the insulation from the ends of the thermocouple wire.
2. Make the thermocouple by joining the wires at one end.
3. Attach the other end to the thermocouple voltmeter. Note that the attachment to the thermocouple reader serves as the reference junction and the location for measuring the resulting EMF.
4. Place the measuring junction (joined end) in the steam bath and record the temperature. How accurate was your thermocouple? Record the reading.

**Part 2: Transient Response of Thermocouples.**

1. Select one of your welded thermocouples. This thermocouple will undergo a step change in temperature by putting it into a hot air jet. If time permits, you will also be required to test your twisted wire thermocouple in the same way.
2. The hot box and measurement system will be described to you by your instructor and the lab technician.
3. You will come away from this lab with a ".txt" file that has temperature and time information. You will use this file for your data reduction.

**DATA REDUCTION FOR PART 2 (Transient Response):**

1. Import the ".txt" file into Mathcad (see the separate handout for detailed instructions). Plot the temperature vs. time data and make the plot fill the entire page. Put on grid lines and appropriate annotation. Print the graph.

2. From your printed graph, pick out 5 pairs of approximately evenly spaced points between the initial temperature and final temperature. Use these data points to estimate the time constant for your thermocouple. To do this, you will need to transform the data and then do an appropriate linear fit to the transformed data. You should be able to use the slope of the transformed data to determine the time constant. Remember to plot both the transformed data (individual points) and the least squares line fit.

3. Repeat the process (transform the data and do a linear regression), ***but this time use all the data in the file.*** If you plan your Mathcad work carefully, this part will require minimum additional effort.

4. Using the time constants determined in steps 2 and 3, plot the two theoretical response curves (temperature vs. time) overlayed on your original measured data. Your plot should have three traces: Raw data, theoretical curve using the time constant from Step 2, and theoretical curve using the time constant from Step 3.

5. Look at the final plot. Which analysis gave you the better result? What are the possible sources of error?

**REPORT:** The submitted report will be in the "Memorandum Report" format. Only Part 2 of this laboratory will be written up.

**COLLABORATION:** There will be one report submitted per student pair. Your instructor will elaborate further.